Renewable and Sustainable Energy Reviews 15 (2011) 5135–5142

Contents lists available at SciVerse ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

The analysis on wind energy electricity generation status, potential and policies in the world

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ARTICLE INFO

Article history:
Received 25 December 2010
Accepted 5 July 2011
Available online 15 September 2011

Keywords:
Wind energy
Analysis
Energy policies

ABSTRACT

Energy is an essential ingredient of socio-economic development and economic growth. Many countries frequently held meetings and discussions has energy agenda. These countries are working to balance energy demand and supply. Renewable energy technology is one of the solutions, which produces energy by transforming natural phenomena into useful energy forms.

Wind energy is a reliable and promising renewable energy. Wind energy becomes more and more attractive as one of the clean renewable energy resources. The installed capacity of electricity generation from wind energy is rapidly increasing in many countries and these countries are implementing variety incentive policies. Therefore, the importance of wind energy is expected to increase much more in the coming decades.

The presented study comprehensively reviews wind energy in terms of three aspects, namely status, potential and policies analyses and assessments, for the first time to the best of the author's knowledge. This review paper covers the status, potential and policies of the wind energy, the issues faced, and the latest research. Also, the current situation, potential and development of the increasing are discussed. This study is presented recommendations for increasing the installed capacity of wind power.

Contents

1. Introduction

The World Energy Forum has predicted that fossil-based oil, coal and gas reserves will be exhausted in less than another 10 decades. Fossil fuels account for over 79% of the primary energy consumed in the world, and 57.7% of that amount is used in the transport sector and are diminishing rapidly [1]. According to the estimation of the International Energy Agency, by the year 2030, the global energy demand will increase at a rate of 1.6%, and approximately 65% of this increase will be expended by the developing countries [2]. The limited fossil energy resource is a critical issue worldwide [3]. The electrical energy production of the world in 2004 was 17,450 TWh and it is estimated that the world will consume 31,657 TWh in 2030. In order to supply the required electricity demand, thousands of new power plants had to be built [4].

Coal provides the largest share of world electricity generation in the reference case. It accounted for 42% of total generation in 2007, and its share is largely unchanged through 2035. With government policies and incentives throughout the world supporting the rapid construction of renewable generation facilities, the renewable share of world generation increases from 18% in 2007 to 23% in 2035 as shown in Fig. 1 [49].

Energy has become a powerful engine of economic and social development to every country, and the total wastage amount of fossil fuel is increasing rapidly in whole world. However, with the rapid industrialization of world, the energy crisis is presented in foresee future. The price of oil in world decreases from about 147 dollars to

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doi:10.1016/j.rser.2011.07.042

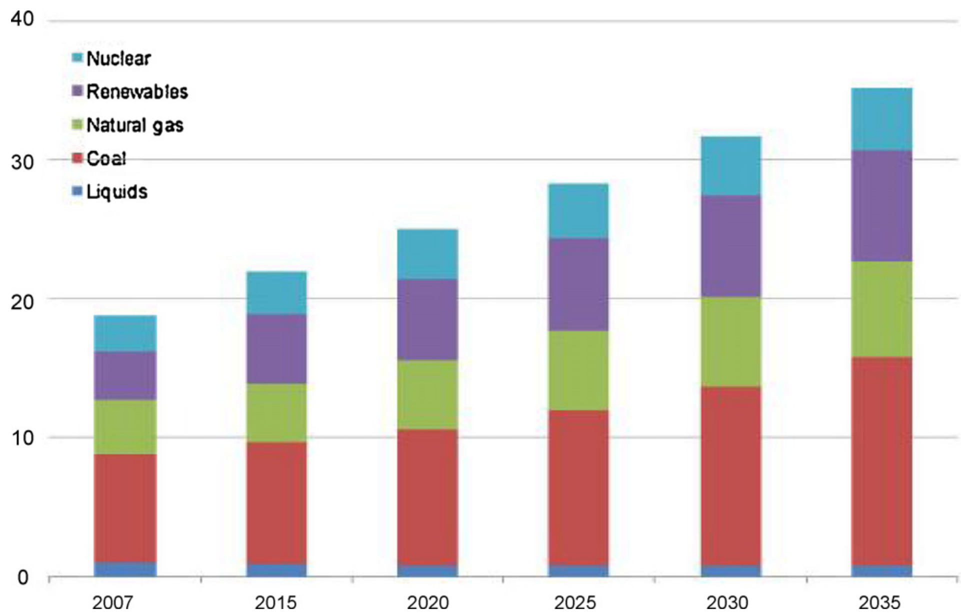


Fig. 1. World electricity generation by fuel, 2007–2035 [49].

about 60 dollars during Finance Crisis, which has decreased about 90 dollars from the vertex [5]. The World Energy Forum has predicted that fossil-based oil, coal and gas reserves will be exhausted in less than another 10 decades. Fossil fuels account for over 79% of the primary energy consumed in the world, and 57.7% of that amount is used in the transport sector and are diminishing rapidly [1].

Renewable energy industries boomed during most of 2008. Worldwide, jobs in renewable energy industries exceeded 3 million in 2009. A 2008 report by the United Nations Environment Programme on jobs from renewable energy observes that while developed economies have shown the most technological leadership in developing viable renewable energy, developing countries are playing a growing role and this is reflected in employment. Some countries keep track of total jobs from renewable energy; for example, the German government estimates 300,000 jobs currently and expects this to increase to 400,000 by 2020. Also, Fig. 2 shows for power plant developers, renewable energy is hard to ignore. Of the roughly 300 GW of new generating capacity of all types added to the world's grids over the past two years, the 140 GW of renewable capacity makes up 47% of the total [50].

The environmental issue has been rising in the worldwide scale such as global warming by exhausting carbon dioxide [6]. In most countries the economic activity that emits the largest amount of CO_2 is electric power generation [7]. This has significant impact on climate change which is now a major issue that has been widely discussed and debated throughout the world. One of the major causes of climate change is the excessive emission of global greenhouse gases (GHGs), such as carbon dioxide and methane, into the atmosphere as a result of human activities [8]. The problems with energy supply and use are related not only to global warming but also to such environmental concerns as air pollution, acid precipitation, ozone depletion, forest destruction, and radioactive substance emissions [9]. Human activities are mainly blamed for the substantial discharge of CO_2. Global discharge of CO_2 related to human activities topped 2.6 billion tons in 2002 and is expected to reach 4.2 billion tons per year in 2030 [10].

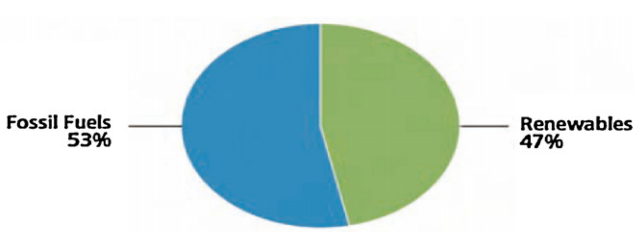


Fig. 2. New power capacity added worldwide by source, 2008–2009 [50].

In developing countries, more than two billion people, mostly living in rural areas, are not served by electrical energy. Much of their energy needs are being met by traditional and non-electric sources, such as human and animal muscle power, firewood, kerosene and animal waste. Problems of environmental destruction caused by mass consumption of fossil energy, as can be seen in the global warming phenomenon, have also rapidly attracted people's concerns. To overcome these problems, wind energy is believed to be a good substitute for other Energy forms due to its safety and is imagined to contribute to the global state of the environment because of its cleanness [11]. The exhaustion of natural resources and the accelerated demand of conventional energy have forced planners and policy makers to look for alternate sources. Renewable energy is energy derived from resources that are regenerative, and do not deplete over time [1]. Recent research and development in Renewable energy sources have shown excellent potential, as a form of supplementary contribution to conventional power generation systems [46]. Alternatives to conventional energy sources, and especially renewable energy, are becoming increasingly attractive because of the limited fossil fuel reserves and the adverse effects associated with the use of fossil fuels [12]. Fig. 3 shows that worldwide renewable energy, existing capacities, at end of 2008.

The geography of renewable energy is changing in ways that suggest a new era of geographic diversity. For example, wind power existed in just a handful of countries in the 1990s but now exists in over 82 countries. Manufacturing leadership is shifting from Europe to Asia as countries like China, India, and South Korea continue to increase their commitments to renewable energy [50]. Wind energy is one of the most important and reliable energy sources among the renewable energy sources. Wind power generation has known a remarkably rapid growth in the past 20 years, and now it is a mature, reliable and efficient technology for electricity production [14]. The total capacity of all wind turbines installed worldwide reached 175 GW in mid-2010, compared with 159 GW by the end of

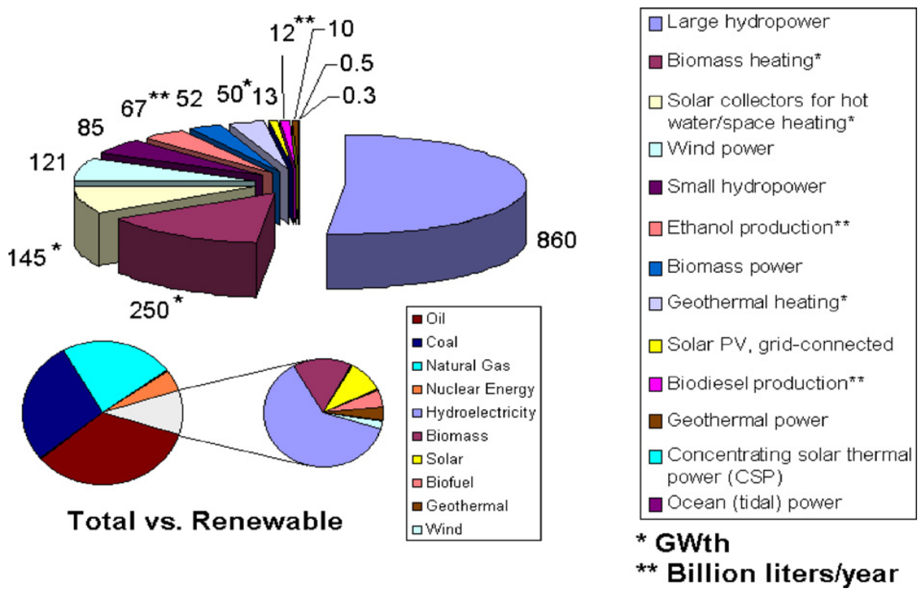


Fig. 3. Worldwide renewable energy, existing capacities, at end of 2008 [13].

2009 [31]. Wind energy is clean and electricity generated by wind turbines won't dirty the air we breathe or emit pollutants like other energy sources – that means less smog, less acid rain and fewer greenhouse gas emissions.

2. Global wind energy markets and production capacity

Recently, wind energy is the growing energy source in the world and wind power is one of the most widely used alternative sources of energy [15]. Today, wind energy is widely used to produce electricity in many countries such as Denmark, Spain, Germany, United States, and India [16].

Wind energy is domestic, independent to abroad, natural and infinite, obtained in the future as same amount, does not cause acid rain or atmospheric heating, no CO_2 emission, no harm to nature and human health, providing fossil fuel saving, no radioactive effect, fast technological development and currency gaining sources [4]. The significance of wind energy originates from its friendly behavior to the environment. Cleanness; wind power is sought wherever possible for conversion to the electricity with the hope that the air pollution as a result of fossil fuel burning will be reduced [17]. Human activities are mainly blamed for the substantial discharge of CO_2. Global discharge of CO_2 related to human activities topped 2.6 billion tons in 2002 and is expected to reach 4.2 billion tons per year in 2030 [10]. To prevent these effects, some potential solutions have evolved including energy conservation through improved energy efficiency, a reduction in fossil fuel use and an increase in environmentally friendly energy supplies [9]. For example; at present, wind turbines in the UK prevent over 2.9 million tones of CO_2 emissions each year. A typical 2 MW wind turbine generates around 5.26 million units of electricity (kWh) each year. This is the same amount of power as would be used by over 1120 homes each year [18]. Wind power is used in a number of different applications, including both grid-connected and stand-alone electricity production, as well as water pumping.

Wind energy is one of the several energy sources alternatives to the conventional primary energy resources, which now power man's industrial and socio-economic activities worldwide [19]. Studies on long-term prospects for the world energy development show that wind energy is an economically efficient and accessible energy resource for a large scale utilization in the coming decades and more remote future [20]. Wind energy can be utilized for a variety of functions ranging from windmills to pumping water and sailing boats. With increasing significance of environmental problems, clean energy generation becomes essential in every aspect of energy consumption [21]. The wind is an inexhaustible resource that can provide significant quantities of energy to support a country's needs. Since earliest recorded history, man has been harnessing the energy of the wind [22].

It is not an easy task to choose a site for a wind turbine because many factors have to be taken into account. The most important factors are wind speed, the energy of the wind, the generator type and the feasibility study [23]. However, wind energy is among the potential alternatives of renewable clean energy to substitute for fossil fuel based energy sources, which contaminate the lower layers of the troposphere. Because of its cleanness, wind power is sought wherever possible for conversion to electricity with the hope that air pollution will be reduced as a result of less fossil fuel burning. In some parts of the USA, up to 20% of the electrical power is generated from wind energy. In fact, after the economic crises in 1973, its importance was increased by economic limitations, and today, there are wind farms in many western European countries [24]. In the Americas, the US market surged by 45%, with its 5244 MW accounting for one-quarter of the global installations in 2007. Installations in the fourth quarter of 2007 alone exceeded the total of 2006, and the United States is on track to overtake Germany as the leader in installed wind power by the end of 2009 [25]. Also, other article says that in the United State of America, the world leader in the field of wind energy capacity since 2008 [26].

The technical potential of onshore wind energy is very large – $20{,}000 \times 10^9$ to $50{,}000 \times 10^9$ kWh per year against the current total annual world electricity consumption of about $15{,}000 \times 10^9$ kWh. The economic potential depends upon factors like average wind speed, statistical wind speed distribution, turbulence intensities and the cost of wind turbine systems. The Global Wind Energy Council is the global forum for the wind energy sector, uniting the wind industry and its representative associations. The members operate in more than 50 countries and represent over 1500 organizations involved in hardware manufacturer, project development, power generation, finance and consultancy, as well as researchers and academics [27]. Over the five-year period end-2004–2009, annual growth rates for cumulative wind power capacity averaged 27%. The capacity installed in 2009 is equivalent to nearly a quarter

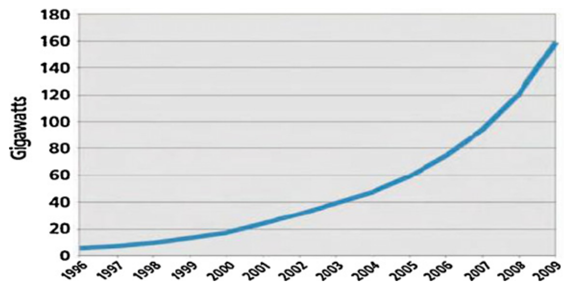


Fig. 4. Wind power, existing world capacity, 1996–2009 [50].

of total global installations, and cumulative capacity has doubled in less than three years. Fig. 4 shows that wind power, existing world capacity, 1996–2009 [50].

The large gap between demand and supply of electricity, increasing cost of imported fossil fuels and worsening air pollution demand an urgent search for energy sources that are cost-effective, reliable and environment-friendly. There has been a lot of recent interest worldwide in developing renewable energy sources. The technology for exploiting wind energy, in particular, has matured to the point that electricity produced from wind turbines now competes in cost with that produced from conventional sources, especially when the cost of environmental damage is factored in. Due to its wide availability and low environmental impact, wind energy is the fastest growing energy resource today [28]. Again the year 2009 brought new records for wind energy utilization around the world: in spite of the global economic crisis, investment in new wind turbines exceeded by far all previous years. Again it can be seen that the installed wind capacity is more than doubling every third year. The market for new wind turbines showed a 42.1% increase and reached an overall size of 38,312 MW, after 26,969 MW in 2008, 19,808 MW in 2007 and 15,111 MW in the year 2006. Ten years ago, the market for new wind turbines had only a size of 4 GW, only one tenth of the size of 2009. The turnover of the wind sector worldwide reached 50 billion €/70 billion US$ in the year 2009, compared with 40 billion € in the previous year [29].

Fig. 5 shows that two pie charts show installed wind generation capacity at the end of 2008 and at the end of 2009 as percentage shares. The countries and regional groupings depicted are Germany, Spain, US, India, China, Denmark and Rest of the World (ROW). The ROW total share has remained at 25% for 2008 and 2009. Germany's installed wind capacity share fell from 20% for 2008 to 16% for 2009. The US share has increased from 20% in 2008 to 22% in 2009. Spain's share has fallen from 14% in 2008 to 12% in 2009. India's share has also fallen from 8% in 2008 to 7% in 2009. China's share has increased from 10% in 2008 to 16% in 2009. Denmark's share has fallen from 3% in 2008 to 2% in 2009. Total installed wind generation capacity grew from 122.2 GW at end 2008 to 160.1 GW at end 2009. In 2009, China more than doubled installed wind capacity to 25.9 GW, overtaking Germany to take second place behind the USA in terms of cumulative installed capacity. China overtook the US in terms of new capacity added (13.7 GW versus 9.9 GW). The US and China together accounted for more than 60% of the total additions to wind capacity. Led by Germany and Spain, Europe remains the largest regional market for wind generation in terms of total installed capacity (77 GW, or 48% of the world total). The fastest growing region over the past five years has been Asia-Pacific, led by China and India. Asia-Pacific's share of installed wind capacity has doubled since 2005, reaching 26% by the end of 2009 [30]. China continued its role as the locomotive of the international wind industry and added 13,800 MW within one year – as the biggest market for new turbines – more than doubling the installations for the fourth year in a row. The USA maintained its number one position in terms of total installed capacity and China became number two in total capacity, only slightly ahead of Germany, both of them with around 26,000 MW of wind capacity installed. Asia accounted for the largest share of new installations (40.4%), followed by North America (28.4%) and Europe fell back to the third place (27.3%). Latin America showed encouraging growth and more than doubled its installations, mainly due to Brazil and Mexico. All wind turbines installed globally by the end of the year 2009 contribute 340 TWh to the worldwide electricity supply which represents 2% of the global electricity demand. This energy amount equals the electricity needs of Italy, an industrialized country with 60 million inhabitants and the seventh largest economy of the world. [31].

The number of installed wind power plants is increasing every year and many nations have made plans to make large investments wind power in the near future [32]. Over the last decade, interest in wind power has increased dramatically in many countries. The installed wind power capacity development of the top 10 countries is shown in Table 1 [33].

The world market for wind turbines saw robust growth in the first half of the year 2010, with approximately 16 GW of new capacity added worldwide. Again, China represents by far the largest market and added 7800 MW within only six months, reaching total installations of almost 34 GW. The USA, still number one in total capacity with 36 GW, saw a major decrease in new installations and added only 1200 MW, followed by India. The five major European markets showed similar growth: Germany added 660 MW, France and the UK 500 MW, Italy 450 MW and Spain 400 MW. [31]. Moreover, wind is becoming an important contributor to European electricity generation. In Denmark wind power provides 20% of power generation. Wind power in Spain has a penetration of 12.4%, larger than hydroelectric generation at 9.3%. In Germany, wind penetration stands at 6.3%, almost double the share of hydro. Wind has a much smaller share in the US – it contributes 1.7% of power generation. But over the past two years wind power has provided more growth in power generated than any other fuel in the USA, and wind now supplies almost twice as much power as oil-fired power plants [30].

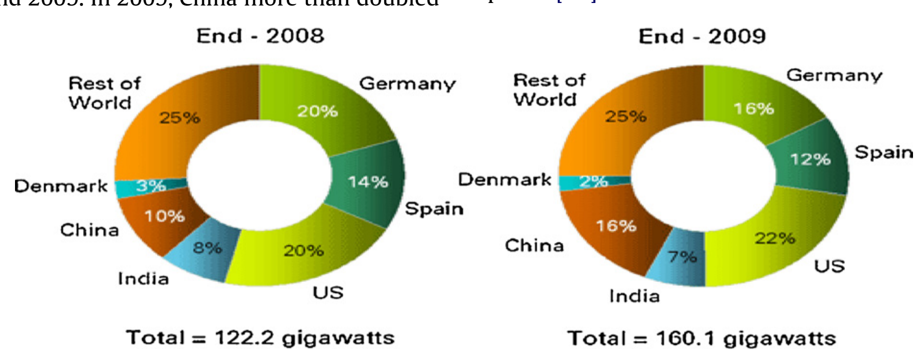


Fig. 5. Installed wind generation capacity at the end of 2008 and at the end of 2009 as percentage shares [31].

Table 1
Top 10 installed wind power capacities (MW) [31–33].

	Country	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010 (June)
1	USA	2554	4275	4685	6374	6740	9149	11,603	16,818	25,170	35,159	36,300
2	China	340	401	468	566	764	1266	2599	5912	12,210	26,010	33,800
3	Germany	6113	8754	12,001	14,609	16,628	18,427	20,622	22,247	23,903	25,777	26,400
4	Spain	2235	3337	4830	6202	8263	10,027	11,630	15,145	16,754	19,149	19,500
5	India	1167	1407	1702	2110	2985	4430	6270	7850	9645	10,925	12,100
6	Italy	427	682	788	904	1265	1718	2123	2726	3736	4850	5300
7	France	79	85	147	198	390	757	1567	2455	3404	4521	5000
8	UK	408	464	552	647	900	1353	1962	2389	3241	4092	4600
9	Portugal	100	127	193	288	562	1022	1716	2130	2862	3535	3800
10	Denmark	2300	2417	2880	3110	3117	3128	3136	3125	3180	3497	3700

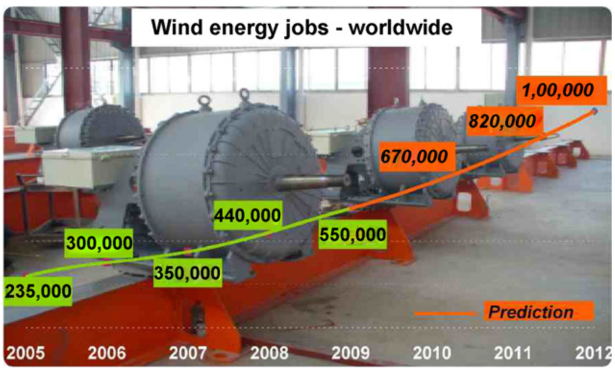


Fig. 6. Wind energy jobs – worldwide [29].

Fig. 6 is indicated that also in 2009 the wind sector worldwide was a major job generator and created new employment: by the end of 2009, 550,000 persons were employed worldwide directly and indirectly in the various branches of the wind sector [29].

Within only four years, the wind sector worldwide more than doubled the number of jobs from 235,000 in 2005 to 550,000 in the year 2009. These 550,000 employees in the wind sector worldwide, most of them highly-skilled jobs, are contributing to the generation of 340 TWh of electricity. By the end of the year 2010, 670,000 employees are expected, and in 2012, the number of jobs is expected to reach one million [29]. Distribution of these people are generally as follows; Germany 100,000; United States 85,000; Spain 42,000; Denmark 22,000; India 10,000 [50].

The growth rate is the relation between the new installed wind power capacity and the installed capacity of the previous year. The highest growth rates of the year 2009 with more than 100% could be found in Mexico which quadrupled its installed capacity, once again in Turkey (132%) which had the highest rate in the previous year, in China (113%) as well as in Morocco (104%) [31]. Fig. 7 shows that top 10 Countries by growth rate in wind energy.

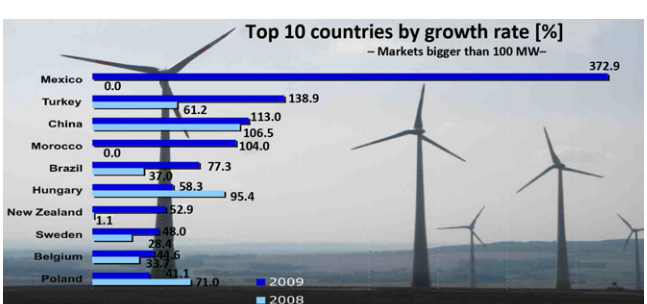


Fig. 7. Top 10 countries by growth rate in wind energy [31].

3. Research and development in wind energy

Trends include new growth in off shore development, the growing popularity of distributed, small scale grid-connected turbines, and new wind projects in a much wider variety of geographical locations around the world and within countries. Firms continue to increase average turbine sizes and improve technologies, such as with gearless designs [50]. The turnover of the wind sector worldwide reached 50 billion/70 billion US$ in the year 2009, compared with 40 billion in the previous year [31]. Increasing the Wind Energy's Contribution to U.S. Electricity Supply, a report released in May 2008 by the U.S. Department of Energy, concludes that the U.S. possesses sufficient and affordable wind resources to obtain at least 20% of its electricity from wind. Achieving the 20% wind vision will dramatically cut greenhouse gas emissions [47].

The electricity output of a turbine is roughly proportional to the rotor area, so fewer larger rotors (on taller towers) use the wind resource more efficiently than more numerous, smaller machines. The largest wind turbines today are 5–6 MW units with a rotor diameter of up to 126 m. Turbines have doubled in size approximately every five years, but a slowdown in this rate is likely for onshore turbines, due to transport, weight and installation constraints [34].

The estimated lifetime of an individual wind turbine is 20–25 years. Life spans may stretch as the technology continues to mature. However, due to the youth of the industry and the re-powering of plants with the latest turbine technology, few turbines have been around long enough to test this assumption. Due to extensive testing and certification, the reliability of wind turbines – the proportion of the time they are technically available for operation – is around 99% [34].

The so-called "feed-in-tariffs" that have provided a stable profitable market for wind generators in Denmark and Sweden historically, and Germany and Spain currently, no longer exist in the United States. Denmark has a long tradition of exploiting wind power. Research and development of new kinds of wind turbines from the late 1970s, combined with favorable government grants towards wind power production, have created a Danish success story [47]. In 2009, European and Chinese firms clearly dominated the wind turbine manufacturing sector. Among individual companies, Danish company Vestas retained its top spot in 2009 compared to 2008, while GE Wind of the United States remained in second place. Suzlon of India also featured among the top 10 global manufacturers as shown in Fig. 8 [50].

4. Cost and profit analysis of wind energy

The main parameters governing wind power economics include the following [48]:

- Investment costs, including auxiliary costs for foundation, grid-connection, and so on.

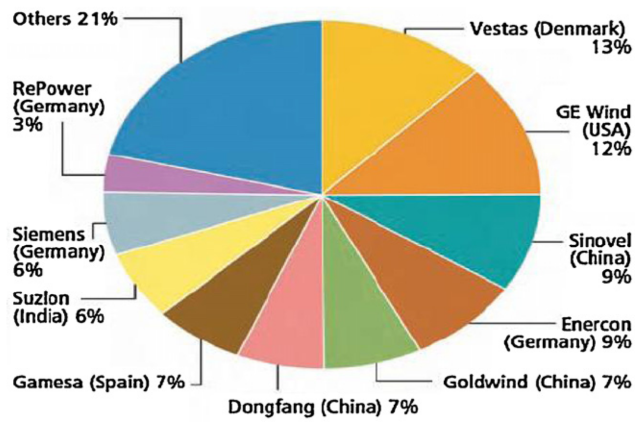


Fig. 8. Market shares of top 10 wind turbine manufacturers, 2009 [50].

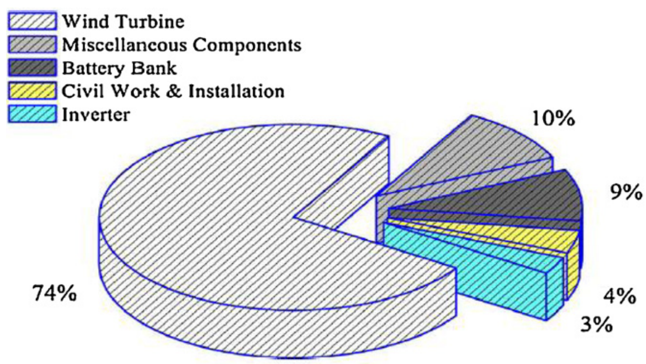


Fig. 9. Cost break-up of a typical WECS Project [36].

- Operation and maintenance (O&M) costs.
- Electricity production/average wind speed.
- Turbine lifetime.
- Discount rate.

The rapid growth in wind energy use is the result of improved efficiency and reduced cost of wind turbines to a level that makes power generation from the wind competitive to that from conventional sources. Furthermore, there is an added advantage that wind power is a non-polluting source of energy [35].

Cost analysis of the electricity supplied by wind energy conversion systems (WECS) is a rather difficult task requiring the estimation of output power generation as well as the cost of the WECS, in addition to the analysis of the wind distribution parameters. Power generation of the WECSs is closely related not only to the system's performance but also to operating conditions, which means the wind characteristics of the site, as well. Therefore, the selection and installing of suitable wind electric generator to produce electrical energy economically in the windy areas requires a number of activities that include the investigation of the source, feasibility assessment, etc. Fig. 9 represents a break-up of relative costs different components of a typical WECS. The specific cost of any WECS in terms of rated power, as read from Table 2, is selected in the band interval (maximum and minimum values) [36]. The major part of the investment is for the wind turbine itself. Civil work & installation, miscellaneous components, battery bank and inverter required 4, 10, 9 and 3% respectively of the total initial investment.

Table 2
Cost of wind turbines based on the rated power [37].

Size (kW)	Cost ($/kW)
Up to 10	2400–3000
100	1250–2000
250 and above	700–1000

The cost of any wind turbine system is expressed in terms of money per kW. The specific cost of turbine systems for different size ranges is given in the table. The specific turbine cost varies according to manufacturers. Thus, choosing of the specific turbine cost can be done by considering a band interval (maximum and minimum values) as given in Table 2 [36].

Of other cost components, dominant ones are, typically, grid-connection, electrical installation and foundation, but other auxiliary costs such as road construction could represent a substantial proportion of total costs. There is considerable variation in the total level of these auxiliary costs, ranging from approximately 24% of total turbine costs in Germany and the UK to less than 20% in Spain and Denmark. The costs depend not only on the country of installation, but also on the size of the turbine [48].

As we see, the cost/kW decreases, with the increase in the system size. For machines sized above 250 kW, the turbine cost may roughly be taken as $750 per kW [37]. In smaller systems, where the recurring annual costs are relatively low, you can determine if a project is viable by using a simple payback approach. Simple payback is a straightforward measure of the number of years. It would take to have your annual energy savings pay for the initial and annual costs of operating the wind energy system. Energy requirements in a remote cabin are about 2 kWh per day. A 500 W wind turbine with a 20 m tower and 220 Ah of batteries will cost about $7500. Operation and maintenance (annual costs) and battery replacement every five years will amount to about 5% of the capital costs or ($7500 × 5%) $375 [38].

The alternative is a small diesel generator which will cost about $2500 and $1.56/kWh to run, including fuel and maintenance.

The net installed cost is the initial cost of the wind energy system, less the original cost of the generator: $7500 – $2500 = $5000.

The net annual savings are the annual cost of the generator: $1.56 per kWh × 2 kWh/day × 365 days = $1139.

Minus the annual cost of operating the wind energy system (which we said was $375): $1139 – $375 = $764.

Simple payback = $5000/$764 = 6.54, or about 6-1/2 years.

Turbine costs have decreased by a factor of four since the 1980s. Since 2004, however they have increased by 20–80%, due to tight supply of turbines and components, and high commodity prices. In 2007, onshore turbine costs ranged from USD 1.2 m to 1.8 m per MW [34].

Determining of wind energy potential for the selected site is made by investigating detailed knowledge of the wind characteristics, such as speed, direction, continuity, and availability. Thus, proper wind turbine selection and micro sitting process for the wind power plants are obtained [39]. Also, to utilize the full power of the wind, the turbine should be located in a constantly high wind speed area. For wind energy application developers, it is necessary to estimate the future energy production of wind farms [40].

At least 83 countries – 41 developed/transition countries and 42 developing countries – have some type of policy to promote renewable power generation. The 10 most common policy types are feed-in tariffs, renewable portfolio standards, capital subsidies or grants, investment tax credits, sales tax or VAT exemptions, green certificate trading, direct energy production payments or tax credits, net metering, direct public investment or financing, and public competitive bidding [50].

The technical development of wind turbines, after the great number of installed machines in the United States during the eighties, has reduced costs on account of the lower probability of failure and of the standard production of many components [41]. For instance, in the United States, wind power receives a tax credit for

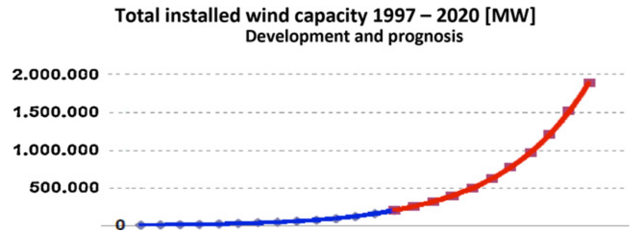


Fig. 10. Total installed wind capacity 1997–2020 (MW) [31].

each kWh produced; at 1.9 cents per kWh in 2006, the credit has a yearly inflationary adjustment. Another tax benefit is accelerated depreciation. Many American states also provide incentives, such as exemption from property tax, mandated purchases, and additional markets for "green credits" [42].

Wind generation also leads to a significantly lower market price particularly during peak periods [43]. Among the renewable and environmental friendly energy sources, wind is one of the cheaper ones. While the MW price of the solar based energy is $72.0 that of wind based energy is $34.0, which is higher than the hydro-based energy which costs $22.0/MW [44].

The growth of the wind-turbine market has been the result of a few concurrent factors. The first of these is the continuous progress of wind-turbine technology, which has led to a drop in the selling price of machines, along with increasing energy conversion efficiency (best-sited plants have recently operated with a capacity factor of around 40%) and higher reliability (availability of up to 95% and even more has been recorded at several plants) [45].

5. Future prospect in wind energy

The IEA Energy Technology Perspectives 2008 publication suggests that in 2050 wind power could supply up to 12% of global demand for electricity – with concentrated effort and technology innovation [34]. By the year 2020, at least 1,500,000 MW can be expected to be installed globally. A recently published study by the Energy Watch Group reveals – as one out of four described scenarios – that by the year 2025 it is even likely to have 7,500,000 MW installed worldwide producing 16,400 TWh. All renewable energies together would exceed 50% of the global electricity supply. As a result, wind energy, along with solar, would conquer a 50% market share of new power plant installations worldwide by 2019. Global non-renewable power generation would peak in 2018 and could be phased out completely by 2037. Also Fig. 10 shows that total installed wind capacity 1997–2020 (MW) [31].

Further growth can especially be expected in the leading wind markets China (with its recently implemented feed-in tariff), USA (with more and more favorable frameworks expected both on national but also on state level), Germany, Spain and India and in many further countries in Europe, especially in Eastern Europe, but also in many Asian and Latin American countries. Major projects are also expected to be implemented in some African countries, notably in South Africa with its feed-in tariff and in North Africa [31].

In Fig. 11 is shown the consequences for wind power production costs according to the following assumptions [48]:

- A learning rate between 9% and 17% is assumed, implying that each time the total installed capacity is doubled, then the costs per kWh wind power is reduced by 9–17%.
- The growth rate of installed capacity is assumed to double cumulative installations every 5th, respectively every 10th year.
- The starting point for the development is the cost of wind power as observed today, i.e. in the range of 5–6 c€/kWh produced for an average medium sized turbine (850–1500 kW) sited at a medium wind regime (average wind speed of 6.3 m/s at a hub height of 50 m).

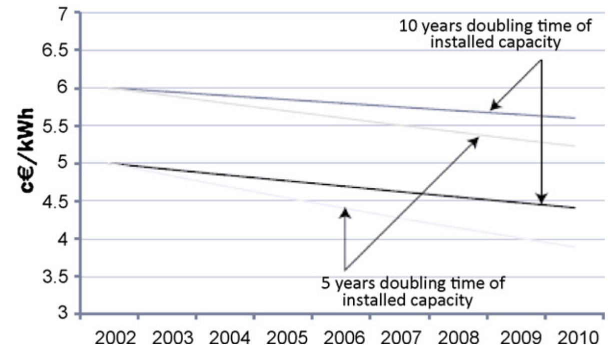


Fig. 11. Using experience curves to illustrate the future development of wind turbine economics until 2010 [48].

6. Conclusion and discussion

Wind power electricity energy generation in the world is growing rapidly. In order to achieve environmentally benign sustainable energy programs, renewable energy sources should be promoted in every stage. This will create a strong basis for the short- and long-term policies [51]. The States should be promoted it, the individual participants should be encouraged and the generation of photovoltaic energy trade and photovoltaic cell production should be incentives. People who can be produced more facilitated their own electricity. Various activities should be organized to increase public awareness and applications. Public offices have an important role for this situation. To allow the widespread application of wind energy technology, there is a need for further R&D improvements in wind energy technologies that can reduce the cost of wind energy systems.

Wind energy source is one of the fastest growing sources of renewable energy sources. The installed capacity of wind power has increased in recent years. In this study, the current situation, potential and development of the increasing are discussed. This study is presented recommendations for increasing the installed capacity of wind power.

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